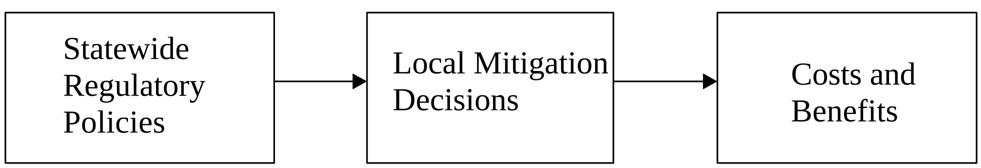
Chapter 11: Statewide Policy Implications

11.1 Introduction

The models and analyses were developed in the context of specific scenarios for reducing exposures from transmission lines, distribution lines and home grounding systems. Typically, we used stretches of distribution and transmission lines between 4 and 50 miles, with detailed assumptions about land use, houses, and population density. We used this localized approach, because most real decisions about the electric power grid are made at this level. The intention was to first provide tools for local decisions and then provide guidance for rolling up the results to statewide land use and power grid policies, such as restricting land use, setting standards, etc.

In theory, this roll up is straightforward. First, the power grid system would be segmented into a much finer set of scenarios than was possible in this project. For example, a finer segmentation would include all voltage classes for transmission and distribution lines, more line configurations, more types of homes, land uses, etc. Second, the Analytica models would be used to analyze EMF alternatives at the scenario level and translated into per-mile costs and benefits. Third, a GIS type approach would be used to identify how many miles of the power grid system exist for each of the scenarios. Fourth, the per-mile results would be applied to the length of miles identified by the GIS analysis to provide an indication of the statewide costs and benefits of EMF policies.

Figure 11.1: Relationship between Statewide Regulation, Local Mitigation, and Consequences



With this idealized statewide roll up one can examine the effects of regulatory policies on local decisions and through the local decisions examine the cost and benefits implications of statewide regulatory policies (see Figure 11.1). Regulatory policies are, in effect, driving local mitigation decisions. For example, if the policy is to implement low cost or no cost EMF mitigation, it will cause the implementation of alternatives like optimal phasing, compact delta configurations, and split phasing with their associated costs and benefits. If the policy is to set a field strength standard of 5 mG at the edge of the right-of-way in residential areas, it will lead to undergrounding for higher voltage transmission lines and some primary distribution lines. The Analytica models can provide the answer to the question: What is the best alternative within a specific scenario, given a statewide policy? These best alternatives and their costs and benefits can then again be rolled up to a statewide level to indicate the costs and benefits of the policy.

The analysis and computer tools that this project developed are suited for this kind of idealized statewide roll up. In practice, however, the few scenarios that we were able to run limit our statewide analysis. Thus, rather than relying directly on the results of the scenarios, we will use the scenario information to create rough low and high per mile estimates of the consequences of mitigation decisions. We will then examine different combinations of assumptions about low and high estimates (for example, assuming low total project cost, high health risk reduction benefits, and low property values benefits) to obtain a first impression of the impact of different assumptions. In addition, we will examine the implications of total project costs for policies that would be implemented on a statewide level.

11.2 Transmission Line Retrofitting

We analyzed three transmission line retrofitting scenarios: Retrofitting a 69kV transmission line on street side poles, retrofitting a 115 kV transmission line on a cleared 50 foot ROW, and retrofitting a 230 kV line on a cleared 50 foot ROW. The 69kV and 115 kV scenarios were located in a fairly dense suburban environment, the 230 kV scenario was in mixed residential, commercial, and rural environments.

We first noted that mitigation measures that were designed to reduce fields only at one or two spans of the line were generally inferior to mitigation measures that were applied to the whole line. We also noted that there typically was one “moderate” mitigation measure (optimal phasing or split phasing) with a relatively high degree of effectiveness in reducing EMFs at a relatively low cost. Undergrounding tended to reduce EMF exposures even more, but at a very high cost. Our statewide analyses therefore focuses on three alternatives:

1. No change,
2. Moderate action (split phasing or optimal phasing),
3. Undergrounding.

We analyzed the results of the three retrofitting models in terms of the equivalent per mile cost of three major consequences: Total Project Cost (TPC), Health Cost, and Property Values. Health costs include all health endpoints (leukemia, brain cancer, breast cancer, and Alzheimer’s disease) considered in this study. Other direct costs (operation and maintenance, conductors losses, and outages) were also high in the scenarios analyzed, but they differed much less across alternatives, and thus are not as relevant for decision making. All costs are discounted at 3%. The low TPC costs assume no financing, while the high TPC costs assume financing. The health cost estimates include all diseases analyzed in this study (leukemia, brain cancer, breast cancer, and Alzheimers’ disease). The low health costs assume a 5% chance that EMF poses a hazard for all diseases, the high costs assume a 20% chance. The low property values cost assumes that 100 homes adjacent to the line are appreciated at 5% when undergrounding, the high property values cost assume a 20% appreciation.

Tables 11.1 and 11.2 show two examples of the eight combinations of low or high TPC, health costs, and property value impacts. Table 11.1 shows the results, assuming low TPC, low health costs and low property values impacts. In this case, undergrounding has the lowest total equivalent cost for the 69kV line, while moderate change is preferred for the 115kV and 230kV lines. Table 11.2 shows the results, assuming high TPC, high health costs, and high property values impacts. In this case, undergrounding is preferred for the 69kV and 115kV lines, but is narrowly edged out by moderate change for the 230kV line.

Table11.1: Per Mile Equivalent Costs for Major Criteria
(Low TPC, Low Health Cost, Low Property Values Impacts)

69 kV Retrofit	**TPC**	**Health**	**Prop. Values**	**Total**
No Change	$0	$125,000	$0	$125,000
Moderate Change	$150,000	$5,000	$0	$155,000
Undergrounding	$750,000	$12,500	-$1,000,000	-$237,500
115 kV Retrofit				
No Change	$0	$350,000	$0	$350,000
Moderate Change	$200,000	$60,000	$0	$260,000
Undergrounding	$1,500,000	$6,000	-$1,000,000	$506,000
230 kV Retrofit				
No Change	$0	$1,000,000	$0	$1,000,000
Moderate Change	$500	$500,000	$0	$500,500
Undergrounding	$3,000,000	$10,000	-$1,000,000	$2,010,000

Table 11.2: Per Mile Equivalent Costs for Major Criteria
(High TPC, High Health Cost, High Property Values Impacts)

69 kV Retrofit	**TPC**	**Health**	**Prop. Values**	**Total**
No Change	$0	$400,000	$0	$400,000
Moderate Change	$300,000	$20,000	$0	$320,000
Undergrounding	$1,500,000	$50,000	-$4,000,000	-$2,450,000
115 kV Retrofit				
No Change	$0	$1,400,000	$0	$1,400,000
Moderate Change	$4,000	$240,000	$0	$244,000
Undergrounding	$3,000,000	$24,000	-$4,000,000	-$976,000
230 kV Retrofit				
No Change	$0	$4,000,000	$0	$4,000,000
Moderate Change	$1,000	$2,000,000	$0	$2,001,000
Undergrounding	$6,000,000	$40,000	-$4,000,000	$2,040,000

Table 11.3 summarizes the results of analyzing all eight combinations of high or low TPC, health costs, and property values impacts. Clearly, the preference for no change, moderate action, or undergrounding is substantially affected by the choice of high or low cost assumptions. Generally, when property values impacts are assumed to be high, undergrounding is the preferred alternative, except for 230 kV lines. In most other cases, moderate action is preferred, except when TPC is high, and health and property values impacts are low. In this case, no change is preferred. There is also a trend to prefer more stringent action for lower voltage classes than for higher ones, because the retrofitting costs are higher for higher voltage classes.

Table 11.3: Summary of Results of Sensitivity Analyses on High and Low Cost Scenarios for TPC, Health, and Property Values

(UG=Undergrounding, MC=Moderate Change, NC=No Change)

Cost Scenario			Preference by Voltage Class		
TPC	**Health**	**Prop. Values**	**69kV**	**115kV**	**230kV**
Low	Low	Low	UG	MC	MC
High	Low	Low	NC	NC	NC
Low	High	High	UG	UG	MC
High	High	High	UG	UG	MC
Low	High	Low	UG	MC	MC
High	High	Low	MC	MC	MC
Low	Low	High	UG	UG	UG
High	Low	High	UG	UG	MC

From the GIS analysis of transmission lines, we can calculate the number of circuit miles of transmission lines of several voltage classes that pass through residential, commercial, industrial, or rangeland and other areas (see Table 11.4). I clear from this table that the vast majority of transmission lines are located outside of residential, industrial, and commercial areas.

Table 11.4: Miles of Transmission Lines by Land Use

	69 kV (60-92)	115 kV (110-161)	230 kV (220-287)
Residential	884	867	753
Commercial/Industrial/Mixed	496	457	491
Other (Agricultural, Rangeland, etc.)	13,460	9,028	11,386
Total	14,840	10,352	12,630

It is tempting to multiply the per-mile estimates from tables like Tables 8.1 and 8.2 by the residential miles of transmission lines displayed in Table 8.4 to obtain state-wide estimates. However, the GIS database shows circuit miles rather than structure miles or corridor miles. Circuit miles are the miles of usually three cables that connect two substations. In many cases, two circuits are placed on one structure as can be seen in many transmission line towers, which carry six cables – three on each side. These are called double-circuit lines and we refer to double circuit miles. Sometimes, multiple structures are placed in the same corridor, in which case we refer to them as corridor-miles. While it is appropriate to estimate TPC on the basis of circuit miles (taking care to distinguish between single circuit and double circuit lines), we would overestimate effects and property values impacts, which should be based on corridor miles.

There is very little data on the percentage of transmission lines, which are double circuit vs. single circuit. One of our consultants gave some very rough estimates for one major utility that suggested that most 230kV lines are double circuit, while most 69 kV lines are single circuit. The 115 kV lines are about evenly split between single and double circuit lines. In our statewide cost estimates, we assume that all 69kV lines are single circuit and all 115kV and 230kV lines are double circuit. This will overestimate the cost of retrofitting the 69kV lines somewhat, while underestimating the cost of retrofitting the higher voltage class lines. Based on these assumptions, and using our scenario calculations as a guide for cost estimates, we created low and high cost estimates for retrofitting transmission lines statewide (see Table 11.5). The Moderate Change case costs $135.6 million for the low TPC and $272 million for the high TPC case. Undergrounding costs $2,475 million for the low TPC case, $4,950 million for the high TPC case.

Table 11.5: Statewide Estimate of Costs of Moderate Change and Undergrounding Transmission Lines

Moderate Change	**Low TPC**	**High TPC**
69kV	$135,000,000	$270,000,000
115 kV	$400,000	$1,600,000
230 kV	$200,000	$400,000
Total	**$135,600,000**	**$272,000,000**
Underground	**Low TPC**	**High TPC**
69kV	$675,000,000	$1,350,000,000
115 kV	$600,000,000	$1,200,000,000
230 kV	$1,200,000,000	$2,400,000,000
Total	**$2,475,000,000**	**$4,950,000,000**

We stated earlier that the impact of the EMF issue on property values of homes near transmission lines impact is very hard to quantify. However, a few calculations are illustrative. For example, using the miles of transmission lines in Table 8.5 and the simple rule of counting single vs. double circuit lines, we calculate approximately 1,700 miles of transmission line corridors that pass through residential areas in California. Assuming 100 homes per mile adjacent to the corridor (50 on each side), 170,000 homes would be affected. Further assuming an average property value of $200,000, the total property value of these homes is $34 billion. A 1% depreciation of these properties would amount to $340 million, a 20% depreciation to $6.8 billion. At the low end, this property value impact is only about 5-10% of the TPC of undergrounding, but at the high end, this could be commensurate to the TPC of undergrounding.

The EMF debate started in 1979, with Wertheimer and Leeper's publication and it became a publicly debated issue in the late 80's, when additional epidemiological findings were published and the media started to pay attention to the issue. Consequently, there are many homeowners, who owned a home near a transmission line, and still own it today. In fact, since the median length of homeownership in California is about 12 years, we estimate that about 50% of the 170,000 homes are still owned by those who owned it prior to EMF becoming a debated public issue. If these homeowners appealed to the PUC to obtain restitution for lost property values and if the PUC complied with the appeal, the total cost of this restitution would range from $170 million to $3.4 billion depending on the percent of depreciation (1% vs. 20%). Some of the stakeholders assumed that any such restitution would be spread to all ratepayers and that undergrounding should be credited with avoiding this cost.

The transmission line retrofitting models have examined only a limited set of engineering measures to reduce EMF exposure (split phasing, optimal phasing, raising pole height, and undergrounding). In addition, we analyzed local mitigation options (e.g., for one or two spans of the line) of each of the mitigation alternatives. Even though we analyzed only a limited set of alternatives formally in the Analytica models, we conducted an informal screening of many more alternatives, and typically found them infeasible or a priori not likely to be cost-effective. In the following paragraphs we discuss the local options and some of the screened out options from a statewide perspective.

We generally found that retrofitting only a few spans of transmission lines was not very cost-effective, because too few people benefited from the EMF reductions. Nevertheless, equity and environmental justice considerations may require policy makers to pay special attention to some stretches of power lines, if they expose sensitive individuals, poor people, and communities of color.

A second version of mitigating only a few stretches of powerline is to mitigate only in high-density residential areas. However, we generally found that moderate mitigation can be cost-effective both for higher and lower population densities. This option also raises ethical and environmental justice issues. People living in low-density population areas would certainly raise the question of why they do not receive equal protection.

One could also consider mitigating only in residential areas, but not in industrial or commercial areas. We have not run commercial or industrial land uses separately with our models, but we would expect moderate options to be cost-effective for them as well, though less so than for residental areas. The main factors contributing to less effectiveness are the lower population densities and shorter periods of exposure.

Increasing the right-of-way (ROW) is usually either impractical or prohibitively expensive in residential areas. In most residential areas, homes are built up to the existing ROW (usually about 50 feet from the center of the transmission line). Increasing the ROW by, say 50 feet would encroach on existing properties and require purchase of land and homes. In all of our scenarios, the cost of purchasing one row of homes on each side of the transmission line would have been prohibitive. For example, purchasing one row of 50 homes on each side of a transmission line at a cost of $200,000 per home would cost $20 million, much higher than the cost of undergrounding. As our new transmission line scenarios show, increasing the ROW is also not very cost-effective in reducing EMF exposure.

Creating larger set backs for currently undeveloped areas than for the developed ones is likely to be less expensive, but this option has other problems. First, it could possible stigmatize the homes that are closer to transmission lines and lead to additional property losses. These losses are almost certainly going to be higher than the health risk reduction benefits due to the new setbacks. Second, there are equity problems associated with this option. For example, should the developers be compensated for reducing their space for development and should the homeowners with a lesser setback be compensated for property losses due to stigmatization?

Electricity conservation is a potentially attractive option, since the costs to the individual customer can be small. We ran some preliminary models with a 10% conservation rate for both residential and commercial customers. We found that EMFs would be reduced roughly in proportion to the reduction of electricity use with the associated proportional decrease in possible health risks and costs. Of course, the main benefit of conservation was the direct savings in electricity bills, which is larger that the imputed reduction of health effects from EMF exposure or pollution.

There are many different types of standards for EMF exposure, including ROW field strength standards and various types of exposure standards. Examining the outputs of our exposure programs provides some insights about the implications of these standards for mitigation, and, as a result, for the costs and benefits of standard setting alternatives. For example, requiring a 2mG field strength standards at the edge of a transmission line ROW, would likely force utilities to underground all transmission lines, while a 20mG standard would only require to underground lines above 230kV and possibly require some moderate actions for lower voltage lines.

For new transmission lines ROW field strength standards have been implemented in some states. However, no state currently requires standards for existing transmission lines. Our exposure analyses lead to the following insights regarding these standards:

1. Field strength standards above 100mG at 50 feet will not require mitigation with the possible exception of 350kV and 500 kV lines.

2. Field strength standards in the neighborhood of 50mG at 50 feet may require mitigation for transmission lines with rated ampacities of 1,000 A, but in many cases, the standard can be achieved by moderate actions.

3. Field strength standards of 10 mG at 50 feet may require undergrounding of some stretches of lines with rated ampacities of 1,000 A or more, but the standard can probably be met with moderate actions for most other lines.

4. Field strength standards below 5 mG at 50 feet may be difficult to meet without undergrounding a significant part of the transmission line system.

Exposure standards (e.g., average milliGauss exposure per person per day) pose additional practical problems. It is very hard to measure exposure of individuals, and it is even more difficult to determine whether an individual exposure standard has been exceeded. In addition, the questions arise, what exposure measure should be used, whether background exposure should be counted, and what time frame to use for exposure.

Some ROWs are accessible as jogging paths, parks, and some even include children's playgrounds. One regulatory option is to eliminate public uses. Our models suggest that exposure in ROWs may be very high, but that the time of exposure in ROWs will be fairly short. Additional modeling would be required to determine the incremental risks of these short-term exposures under different assumptions and parameters. A simple regulatory option is to post warning labels at or near sources of high EMF fields. The implications of these warning labels on people's behavior, on assumed responsibility, and liability have yet to be studied. Our analysis does not provide any insights in this regard.

Many utilities provide information packets about EMF exposure to customers. These packets typically inform customers about the sources of EMF exposure and they discuss the inconclusive state of research. Our models do not address the effectiveness of information options.

We found that research on a possible EMF health link is valuable, as long as three conditions are met:

1. the equivalent costs of health effects exceed the cost of mitigation;

2. the mitigation costs are fairly expensive;

3. alternative environmental and health research priorities under the control of the utility industry are not more cost beneficial.

The first two conditions are met, even if we only consider the transmission line system in California. The third condition is open to contention.

11.3 Siting and Configuring New Transmission Lines

We analyzed three transmission line configurations for a new 115kV line: Triangular post, split phase, and undergrounding. The primary purpose of these scenarios was to examine the effects of two land use alternatives: Selecting routes with lower population density and increasing the ROW. An additional purpose was to determine the effects of siting a new 115 kV transmission line with an existing 33kV underbuilt line.

The key insights are that the differential costs of the land use alternatives (different routes and different sizes of the ROW) dominate the differences between the engineering mitigation options. In the case of different routes, the shorter route has the advantage of lower total project costs, partly because of lesser structures and construction costs, partly because of lower land acquisition costs. In the case of different ROWs, the smaller ROW has the advantage of substantially lower land acquisition costs.

One can achieve some decreases in expected health effects by re-routing and increasing the ROWs, but these decreases are small compared to the decreases that one can achieve by split phasing or undergrounding. In most scenarios split phasing (with shorter routes and smaller ROWs) is the preferred option under many assumptions.

The major limitation of these scenarios for generalization to a statewide policy level is that split phasing is not always possible. For example, when building a 230 kV line, the structures are typically designed to carry two circuits. We assume, without having run a specific scenario, that reverse phasing is a cost-effective mitigation strategy in this case.

Another limitation is that we have not fully analyzed the effect of building a new transmission line on the loads and corresponding EMF exposures on other lines in the local grid. Keeney (1997) makes the point that building a new line may in fact decrease health risks under some conditions. For example, re-distributing the loads between the existing and the new line could actually reduce the total number of people exposed above a threshold. We have run an exposure model that confirms Keeney's theoretical calculations, but we have not embedded these results in a full Analytica model.

Deciding on whether to upgrade an existing line versus building a new one, how to route the line, and what ROW to choose has profound equity and environmental justice implications. Clearly the exposure and risk equity issue is pertinent for deciding on whether to upgrade or to build a new line. Building a new line will have significant impacts on residents and homes along the new route. Increasing the ROW for new lines could lead to stigmatization of homes near smaller ROWs. Because of these equity and environmental issues, it is particularly important that environmental justice principles and processes be followed when upgrading or building new lines (see chapter 10).

Increasing the tower or pole height has only limited exposure reduction effects compared to split phasing, reverse phasing and undergrounding. Local alternatives (e.g., re-routing around schools) also have limited effects, but environmental justice concerns may override the cost-benefit considerations. Conservation could reduce the need for upgrading existing lines or building new lines.

The regulatory policies discussed previously (retrofitting existing transmission lines) apply to new transmission lines as well. In particular, low field strength standards at the edge of ROW will force either split phasing, reverse phasing, or undergrounding, depending on the numerical value of the standard and the configuration, voltage class, and loads on the line. If warning labels or other information are provided for new transmission lines, it would only be natural to provide them also for existing transmission lines. Continuing research is likely to be valuable under many assumptions.

11.4 Distribution Line Retrofitting

We analyzed two retrofitting scenarios for distribution lines. Both are for four-mile stretches of primary distribution lines, one with a four-wire configuration and one with a three-wire configuration. As with the transmission line retrofitting scenarios, we observed that for all model runs the options that mitigated only a few spans of the distribution lines were inferior to those that mitigated the whole line. Consequently, we will only generalize from the “whole line” scenarios. In addition, we noticed that all results from the two scenarios are identical, except for health effects, which are somewhat higher for the three-wire configuration. Finally, we noticed that the most cost-effective “moderate action” alternative seems to be conversion to a compact delta configuration.

We calculated the equivalent per mile cost of three major consequences: Total Project Cost (TPC), Health Cost, and Property Values. Other direct costs (operation and maintenance, conductor losses, and outages) were also high in the scenarios analyzed, but they differed much less across alternatives, and thus are not as relevant for decision making. All costs were discounted at 3%. The moderate action is to convert the line to a compact delta configuration. The low TPC costs assume no financing, while the high TPC costs assume financing. Health costs included all diseases considered in this study (leukemia, brain cancer, breast cancer, and Alzheimer’s disease). The low health costs assume a 5% chance that EMF poses a hazard for all health end points, the high costs assume a 20% chance. The risk ratio was assumed to be 2 at 2 mG or an equivalent exposure level. The low property values cost assumes that 100 homes adjacent to the line are appreciated at 2.5% when undergrounding, the high property values cost assume a 10% appreciation.

Table 11.6 shows the results, assuming low TPC, low health cost, and low property values impacts. In this case moderate action is the preferred (lowest cost) alternative. Table 11.7 shows the results, assuming high TPC, high health costs, and high property values impacts. In this case, undergrounding is the preferred alternative. In general, the conclusion from analyzing the eight combinations of low and high costs are very straightforward: When property value impacts are assumed to be low, moderate action is preferred. When property values are assumed to be high, undergrounding is preferred. Thus, the results depend only on the assumptions about the property value benefits of undergrounding.

Table 11.6: Per Mile Equivalent Cost of Retrofitting Distribution Lines
(Low TPC, Low Health Cost, Low Property Values Impacts)

	TPC	Health	Prop. Values	Total
No Change	$0	$150,000	$0	$150,000
Moderate Change	$35,000	$25,000	$0	$60,000
Undergrounding	$750,000	$2,500	-$500,000	$252,500

Table 11.7: Per Mile Equivalent Cost of Retrofitting Distribution Lines
(High TPC, High Health Cost, High Property Values Impacts)

	TPC	Health	Prop. Values	Total
No Change	$0	$600,000	$0	$600,000
Moderate Change	$70,000	$100,000	$0	$170,000
Undergrounding	$1,500,000	$10,000	-$2,000,000	-$490,000

Table 11.8 shows the statewide estimates of the low and high total project costs. If we assume that 6,700 miles (see page 13) require retrofitting, these costs range from $5 billion to $10 billion.

Table 11.8: Statewide Estimates of Costs of Retrofitting Distribution Lines

6,700 miles	Low TPC	High TPC
Moderate Change	$234,500,000	$469,000,000
Undergrounding	$5,025,000,000	$10,050,000,000

A few calculations of property value impacts for homes near distribution lines are again illustrative. Assuming that 6,700 miles of distribution lines produce elevated fields and that 50 homes per mile are adjacent to the distribution line about 335,000 homes could be affected. Further assuming an average property value of $200,000, the total property value of these homes is $67 billion. A 1% depreciation of these properties would amount to $670 million, a 10% depreciation would amount to $6.74 billion. At the low end, this property value impact is only about 10%of the TPC of undergrounding, but at the high end, it is close to the cost of undergrounding. About 50% of the homeowners lived in their homes when the EMF debate became a public issue (about 10-15 years ago). If these homeowners appealed to the PUC to obtain restitution for losses in property values and if the PUC complied with the appeal, the total cost of this restitution would range from $335 million to $3.4 billion depending on the percent of depreciation (1% vs. 10%). Some of the stakeholders assumed that any such restitution would be spread to all ratepayers and that undergrounding should be credited with avoiding this cost.

As in the transmission line scenarios, mitigating a few stretches of distribution lines did not seem very cost-effective and it had negative equity and environmental justice implications. Increasing the ROW is often impossible for distribution lines. These lines are primarily located on the street side or in backyard areas and they can run very close to homes. Conservation will have a health effect impact by reducing the effects roughly proportional to the reduction of electricity consumption.

Field strengths in the close vicinity of primary distribution lines can be as high as 10 mG. Standards in the neighborhood of 5mG may require conversion to compacts delta configurations or undergrounding of long stretches of primary distribution lines.

Exposure standards are impractical for reasons discussed in the transmission line section. Restriction of the access to the ROW is difficult, because there are so many different activities that occur in backyards, fronts of home and on street sides. Providing warning labels and information may be a useful policy to educate residents and to assure that they make simple arrangements to avoid extended exposure in high field areas. Research is even more valuable for distribution line issues than for transmission lines, since more is at stake.

We have not explicitly modeled the effects of secondary distribution lines. However, the main EMF exposure from secondary distribution lines will occur at the service drop, and our home grounding models capture this effect.

11.5 Home Grounding Systems

The home grounding models were run for individual houses, since most decisions are made at that level. The analyses only concerned homes with elevated fields due to net currents on the water pipe. According to Zafanella (1993) between 5% and 10% of U.S. homes have such elevated fields. Using many assumptions and parameter values, the general finding was that for homes with elevated fields from home grounding systems, insulating the water pipe by inserting a piece of plastic pipe was the preferred option. A homeowner can eliminate the incremental risk from this elevated field by insulating the water pipe in this way, for a cost between $200 and $500.

Table 11.9 shows the equivalent costs for one of the home grounding. In both the low cost and the high cost scenario, insulating the pipe is the preferred option. Health costs were estimated using all diseases considered in this study, a degree of certainty that a hazard exists of 0.10 and a risk ratio of 2. The time horizon in this case was ten years, roughly the length of home ownership in California. Table 11.10 shows the implications of applying these low and high costs to either 5% or 10% of the homes in California. These costs are fairly small compared to the costs of retrofitting transmission and distribution lines. We also analyzed improving the net return or changing living arrangements. Under most reasonable assumptions insulating the pipe is the preferred option.

Table 11.9: Equivalent Costs Retrofitting the Home Grounding System (Single Home)

High Cost Scenario	Health	Cost	Total
Do Nothing	$562	$0	$562
Insulate Pipe	$0	$500	$500
Low Cost Scenario	**Health**	**Cost**	**Total**
Do Nothing	$562	$0	$562
Insulate Pipe	$0	$200	$200

Table 11.10: Equivalent Cost of Retrofitting Home Grounding Systems (California)

	Low Cost	High Cost
5% of Homes	$110,000,000	$275,000,000
10% of Homes	$220,000,000	$550,000,000

It is tempting to conclude from our model runs that a reasonable regulatory policy would be to recommend to homeowners to insulate the water pipe, if their homes have elevated fields from grounding system. However, there are two caveats: First, depending on the degree on certainty that EMF is a hazard, this may in fact, not be the best option. Second, there may be indirect risks as a consequence of insulating the pipe, including electrocution hazards and increased fire hazards (see von Winterfeldt and Trauger, 1996).

11.6 Cost Estimates for All Sources

Table 11.11 is a summary of cost estimates for all sources of EMF exposure using the low estimates of retrofitting costs. Table 8.12 shows the same estimates using the high cost estimates. Tables 11.13 and 11.14 shows these results in terms of percent of ten years of utility revenues of the sort experienced in the 1990's and in terms of the number of deaths that would need to be avoided to make retrofitting a preferred alternative. Ten years of revenue were used on the assumption that it would take at least a decade to accomplish any of the retrofits discussed.

Table 11.11: Unit and Statewide Estimates of the Costs of EMF Mitigation (Low Cost Estimates)

Source	Miles/Homes	Cost/Unit (Mile or Home)		Statewide Cost	
		Moderate	Underground	Moderate	Underground
Transmission (69 kV)	900 miles/sgl. circuit	$150,000	$750,000	$135,000,000	$675,000,000
Transmission (115 kV)	400 miles/dbl. circuit	$2,000	$1,500,000	$800,000	$600,000,000
Transmission (230 kV)	400 miles/dbl. circuit	$500	$3,000,000	$200,000	$1,200,000,000
Distribution	6,700 miles	$35,000	$750,000	234,500,000	$5,025,000,000
Home Grounding	550,000 homes	$200	$200	$110,000,000	$110,000,000
TOTAL				**$480,500,000**	**$7,610,000,000**

Table 11.12: Unit and Statewide Estimates of the Costs of EMF Mitigation (High Cost Estimates)

Source	Miles/Homes	Cost/Unit (Mile or Home)		Statewide Cost	
		Moderate	Underground	Moderate	Underground
Transmission (69 kV)	900 miles/sgl. circuit	$300,000	$1,500,000	$270,000,000	$1,350,000,000
Transmission (115 kV)	400 miles/dbl. circuit	$4,000	$3,000,000	$1,600,000	$1,200,000,000
Transmission (230 kV)	400 miles/dbl. circuit	$1,000	$6,000,000	$400,000	$2,400,000,000
Distribution	6,700 miles	$70,000	$1,500,000	469,000,000	$10,050,000,000
Home Grounding	550,000 homes	$500	$500	$275,000,000	$275,000,000
TOTAL				**$1,016,000,000**	**$15,275,000,000**

Table 11.13: Statewide Costs Expressed as a Percent of Utility Revenues and Lives Saved Required to Justify Mitigation Cost (Low Cost Estimates)

Source	Statewide Cost		Percent of 10 Year Revenue		Lives Saved to Justify Cost*	
	Moderate	Underground	Moderate	Underground	Moderate	Underground
Transmission	$136,000,000	$2,475,000,000	0.06%	1.13%	27	495
Distribution	234,500,000	$5,025,000,000	0.11%	2.28%	47	1,005
Home Grounding	$110,000,000	$110,000,000	0.05%	0.05%	22	22
TOTAL	**$480,500,000**	**$7,610,000,000**	**0.22%**	**3.46%**	96	1,522

*Over 35 years assuming $5 million/life

Table 11.14 : Statewide Costs Expressed as a Percent of Utility Revenues and Lives Saved Required to Justify Mitigation Cost (High Cost Estimates)

Source	Statewide Cost		Percent of 10 Year Revenue		Lives Saved to Justify Cost*	
	Moderate	Underground	Moderate	Underground	Moderate	Underground
Transmission	$272,000,000	$4,950,000,000	0.12%	2.25%	54	990
Distribution	469,000,000	$10,050,000,000	0.21%	4.57%	94	2,010
Home Grounding	$275,000,000	$275,000,000	0.13%	0.13%	55	55
TOTAL	**$1,016,000,000**	**$15,275,000,000**	**0.46%**	**6.94%**	203	3,055

*Over 35 years assuming $5 million/life

11.7 Conclusions and Caveats

As stated in the introduction, the objective of this project was to provide decision-makers with analysis and computer tools to examine the consequences of alternative policies to reduce EMF exposure from California power grid sources. The project created three analysis and computer tools:

1. an exposure model,
2. a set of decision analysis models in Analytica

These tools were designed so that a user can examine any scenario for decisions and policies about mitigating EMF exposures from power grid sources. The tools were highly parameterized to allow users to input their own data and estimates.

The models were illustrated with ten scenarios. Sensitivity analyses were conducted to determine which assumptions and parameter values made a difference to the decisions about mitigating EMF exposure.

In the process of exercising the models in specific scenarios, we gained several insights. Perhaps the most important one was that only four criteria had a major impact on the decisions:

1. EMF health effects,
2. direct costs to utilities (primarily total project cost)
3. outages,
4. property values.
5.

This result is consistent with Sage's (1999) analysis, which was performed for stakeholders representing residents living near transmission lines. The fact that we could narrow down the impacts of EMF mitigation options is important, because it helps to focus the policy debate on the criteria that matter.

Another result of exercising the models was that moderate options (optimal phasing, split phasing, compact delta configurations) were attractive under many assumptions and parameter values, because they led to significant exposure reductions at a fairly low cost. Undergrounding also can be an attractive option, if it creates property values impacts commensurable with the total project costs.

Which of the three contenders (no change, moderate engineering change, or undergounding) is best, depends on the stakeholder choices of model parameters and assumptions. The "No Change" alternative is best when stakeholders make the following choices:

- financing of the cost of mitigation
- low discount rate for financed TPC
- high discount rate for health costs
- leukemia as the only health endpoint
- low estimates of the probability of hazard and the risk ratio
- low value tradeoffs for health risks
- large multipliers for the costs of mitigation
- low or no property value impacts

Undergrounding is favored when making the following choices:

- no financing of the costs of mitigation,
- high discount rates for financed TPC
- low discount rate for health costs
- all health endpoints
- high estimates of the probability of hazard and the risk ratio
- high value tradeoffs for health risks
- base case cost or low cost multipliers for undergrounding
- high property values impacts

For most intermediate choices, the moderate engineering changes (optimal phasing, reverse phasing, split phasing, or compact delta) are favored by the analyses.

Waiting for research can be an appropriate strategy under some conditions. Furthermore, the value-of-information analysis shows that it may be reasonable to fund research at a fairly substantial level.

There are several caveats that temper these conclusions. First, most conclusions are based on the assumption that there is some probability of a health hazard due to EMF. Second, many conclusions about the value of undergrounding depend on assuming property values depreciations or appreciations, which are still widely disputed. Third, many estimates were based on conservative assumptions made to magnify the potential impact of a criterion on the decision. Fourth, this analysis was based on very limited knowledge on the number of homes affected by transmission and distribution lines and the number of transmission and distribution lines that may be candidates for EMF mitigation.

Several factual issues were matters of intense debate among the stakeholders and little information was available, or the information was considered proprietary by the utilities. In some cases this study had to rely entirely on the utility companies to provide this information. The model allows assumptions within the range of estimates favored by different stakeholders. If the different estimates lead to different policy options, the only solution is for the PUC to have a mutually accepted third party provide reliable information on the following issues:

1. the cost of retrofitting existing lines as a function of soil condition and land use, and other factors

2. the reliability of overhead and underground transmission and distribution lines as a function of age and type of technology

3. the conductor losses from operating existing and new lines as a function of line and cable type
4. the operation and maintenance costs of different types of lines

In addition, the following information would be useful to improve the statewide roll up:

1. the number of corridor miles of transmission and distribution lines in California that produce elevated fields in homes

2. a categorization of the corridor miles in 1) as to the number of circuits and types of lines (voltage class, overhead vs. underground), with associated miles per category

3. the number of homes in California that are exposed to elevated fields

Once this information is acquired it can be inserted into the decision models to determine, if the conclusions would be altered.

The ultimate test of the analysis and computer tools is to put them to use in real policy and mitigation decisions. The generalizations described in this chapter still need to be confirmed with many more scenarios and many more model runs. The project has provided the tools for doing this. To develop policies with these models, decision makers will need to develop experience with exercising them, conducting sensitivity analysis from various stakeholders' perspectives, and use judgment to form policies. More importantly, the analyses have to be improved by collecting additional information as outlined above.

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